Operative Techniques in Thoracic and Cardiovascular Surgery

Robotic Approach to Patent Ductus Arteriosus or Vascular Rings

Emile A. Bacha, MD, and Pedro J. del Nido, MD

Patent ductus arteriosus (PDA) clip ligation and vascular ring division are among the oldest procedures performed in congenital heart surgery and comprise a large amount of so-called closed-heart congenital heart procedures. Although controversies still exist regarding closure of small, inaudible PDAs, the need to close larger PDAs in the non-preterm infant is well established. Vascular ring division is always indicated in the presence of symptoms and should be considered in asymptomatic patients with evidence for airway compression.

The first successful video-assisted thoracoscopic (VATS) PDA clip ligation was performed in 1993,[1] and VATS techniques were eventually applied to other closed-heart procedures, including vascular ring division.[2] This technique is now our preferred method of PDA clip ligation in non-preterm infants and for nonpatent vascular rings.[3] In 2002, the first successful robotic PDA clip ligation was reported.[4] The introduction of robotic surgical systems represents a further step in the evolution of endoscopic instrumentation.[5,6] These computer-enhanced systems offer three-dimensional visualization and significantly improved instrumentation, with motion scaling and a wrist mechanism that allows surgeons to perform complex cardiac procedures, including coronary artery bypass, mitral and aortic valve replacement, and atrial septal defect closure, through small incisions in adult patients. The da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA) consists of two primary components: the surgeon's viewing and control console, and the surgical arm unit that positions and maneuvers detachable surgical EndoWrist instruments. These pencil-sized instruments, which possess small mechanical wrists with 7° of motion, are designed to provide the dexterity of the surgeon's forearm and wrist at the operative site through entry ports less than 1 cm in size. One port allows access for the endoscope, and the other two ports provide access for surgical instruments. The wrists of the surgical instruments mimic the motions made by the operating surgeon, who sits at a console removed from the operating table. The surgeon peers through an eyepiece that provides high-definition, full-color, magnified three-dimensional images of the surgical site provided by the endoscope and controls the instrument arms in real-time by manipulating modified joysticks.[7] Pediatric patients present specific problems mostly related to their smaller chest cavity. Although 5-mm instruments and a 5-mm single-channel scope have been developed, our current exclusion criteria for robotic surgery are age less than 24 months and a body weight of less than 14 kg. Patients who are excluded for those reasons are operated with VATS techniques. The robotic approach offers significant advantages over VATS because of the three-dimensional endoscopic view, which mimics the depth perception in "open" surgery, and the markedly enhanced intracorporeal dexterity due to the intrathoracic "wristed" instrumentation. Thus, getting around tight corners and circumferential dissection of a vascular structure becomes much easier. Compared with open surgery, the lack of tactile feedback remains a disadvantage, although one rapidly gets accustomed to compensate for that with visual clues.

Harvard Medical School, Children's Hospital Boston, Boston, MA.
Address reprint requests to Emile A. Bacha, MD, Associate Professor of Surgery, Harvard Medical School, Senior Associate in Cardiac Surgery, Children's Hospital Boston, 300 Longwood Avenue, Bader 273, Boston, MA 02115. E-mail: emile.bacha@cardio.chboston.org

doi:10.1053/j.optechstcvs.2007.09.002

Operative Technique

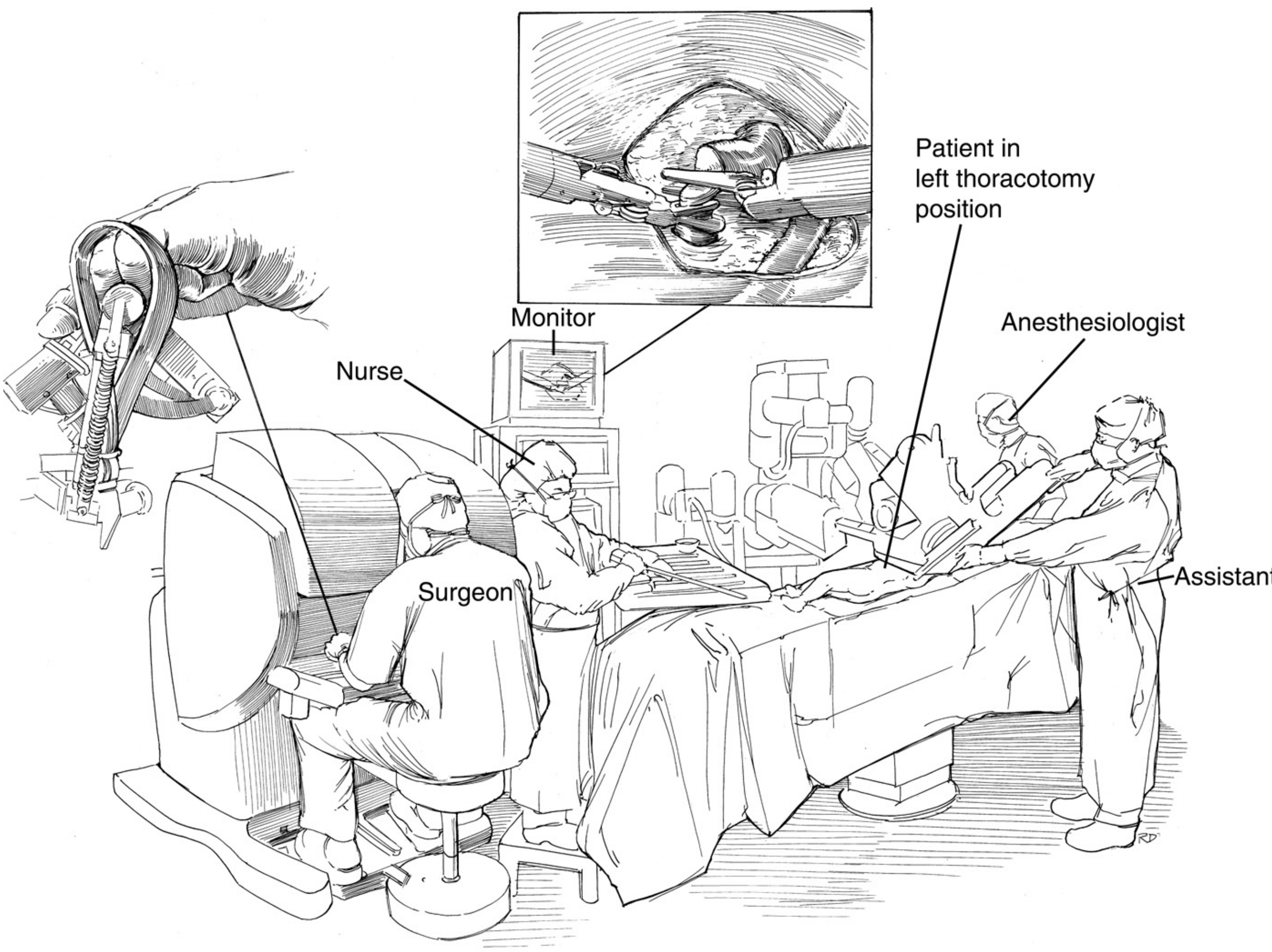


Figure 1 After general anesthesia and single-lumen endotracheal intubation with a bronchial blocker in the left mainstem brochus, the patient is positioned in a right lateral decubitus position (15 to 20°, slightly prone) to allow easier retraction of the left lung and better visualization of the surgical field. The left lung is retracted with an endoscopic fan retractor. It is important to retract the left upper lobe and the superior segment of the left lower lobe. Routine monitoring includes transcutaneous oxygen saturation, continuous end-tidal carbon dioxide, blood pressure, and an electrocardiogram. The robotic surgical cart is positioned at the cranial end of the operating table, angled 30° to the patient's left side. The operating surgeon then sits at the master console, and, after surveying the anatomy, typically begins the dissection using Debakey forceps as a left instrument and an electrocautery spatula as a right instrument. It helps to have a first assistant with robotic experience.

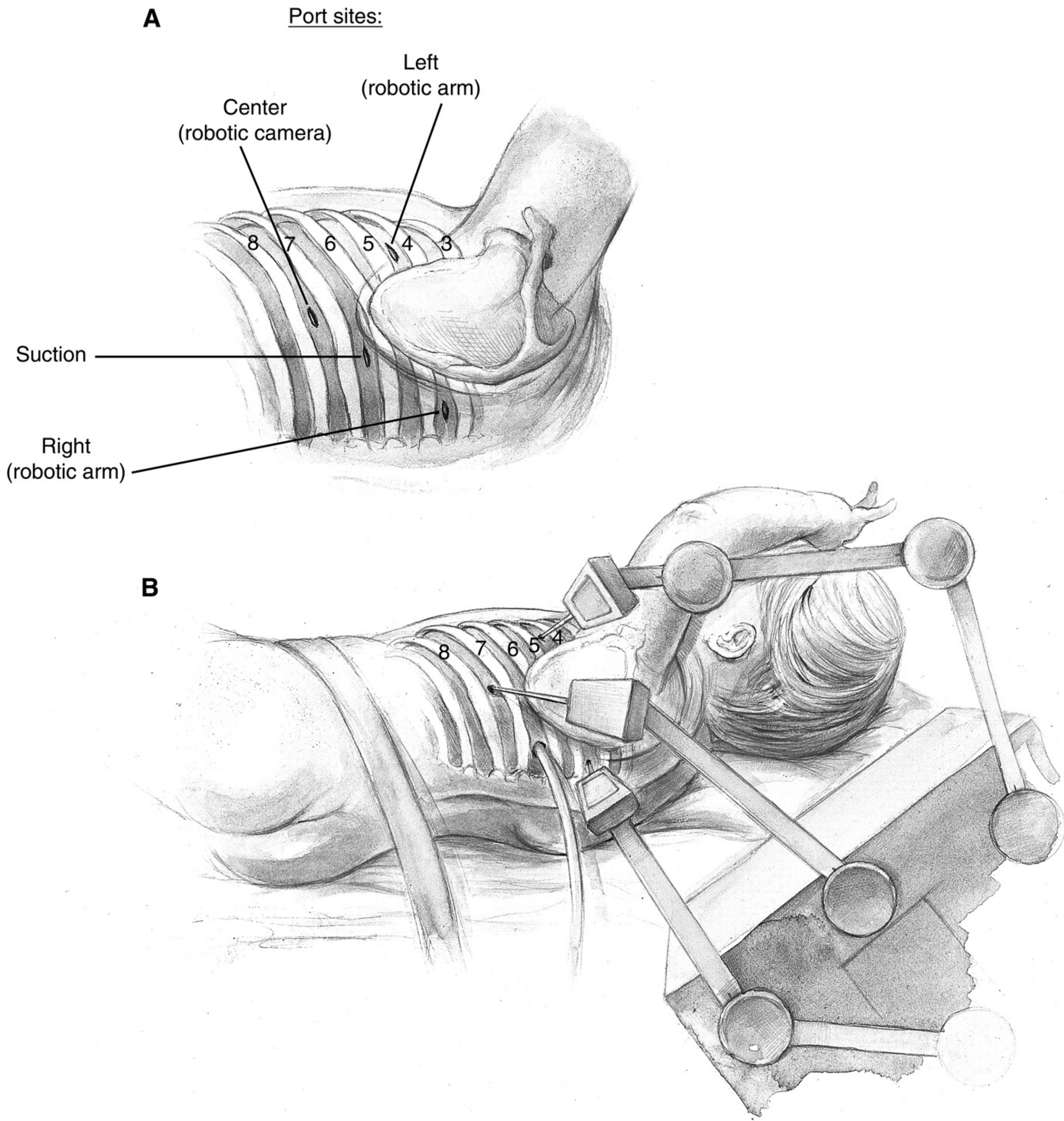


Figure 2 (A) Three thoracoscopic trocars are placed in the left hemithorax to accommodate the camera and the two robotic manipulators. The left and right instrument ports are placed in the third intercostal space along the anterior axillary line and in the posterior sixth intercostal space behind the scapula, respectively. The camera port is placed in the fifth intercostal space. (B) An additional small utility incision is placed between the left instrument and camera incisions to allow insertion of an endoscopic lung fan retractor. After thoracoscopic verification of the anatomy, the 30° camera is attached to the robotic cart, and the robotic surgical instruments are placed through the left and right trocars. In smaller children, because of the short distance between ports and the dissection area, free motion of the instrument heads can be restricted. This can be compensated for by moving the anterior and posterior instrument ports caudally by 3 to 4 cm. This allows for passage of a longer portion of instrument shaft inside the thoracic cavity, thus freeing up the entire instrument tip. The proximal joint ("micro-wrist") can be simply kept bent at 90°, resulting in the same instrument head orientation as if coming in from a port located just above the dissection area.

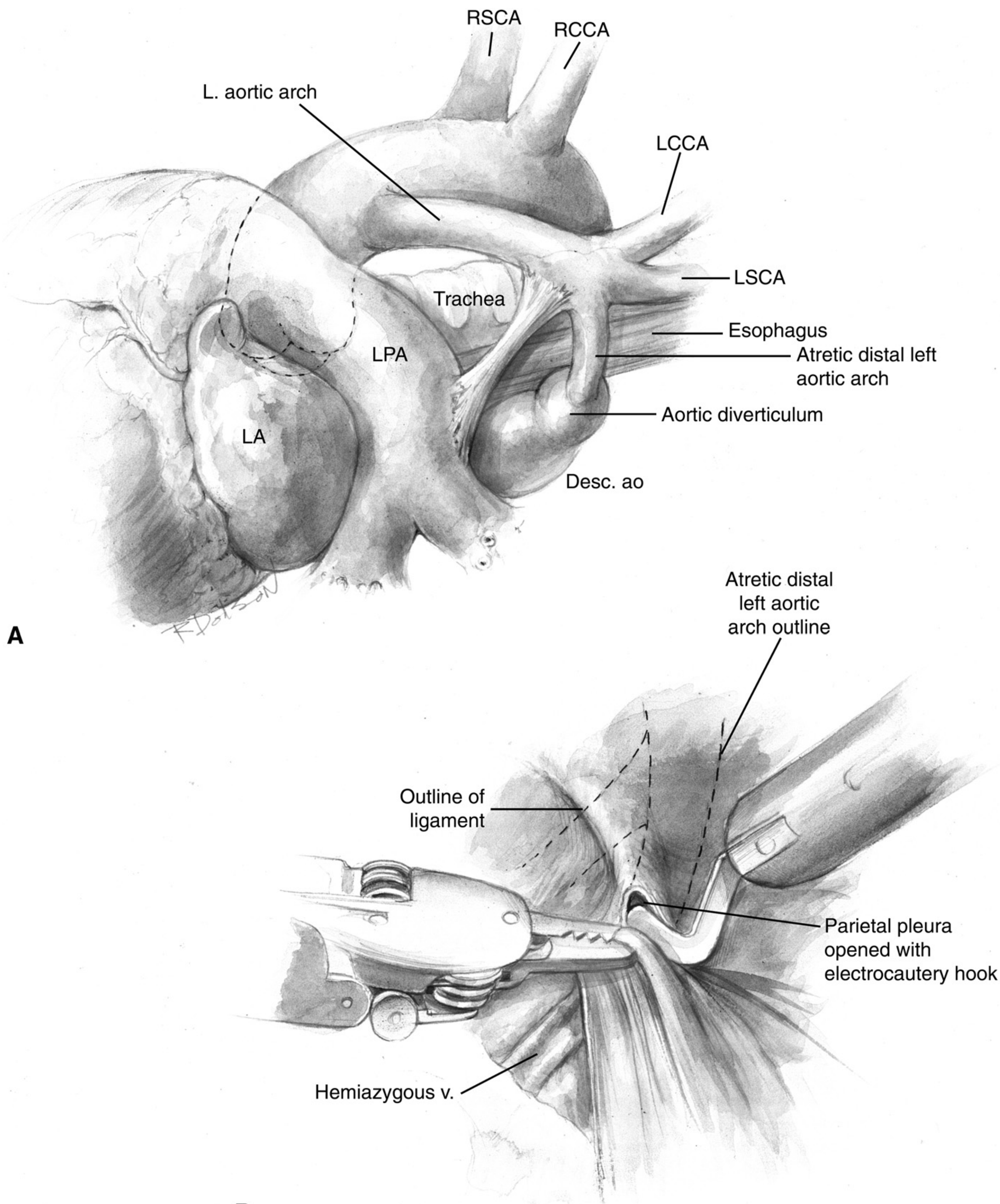
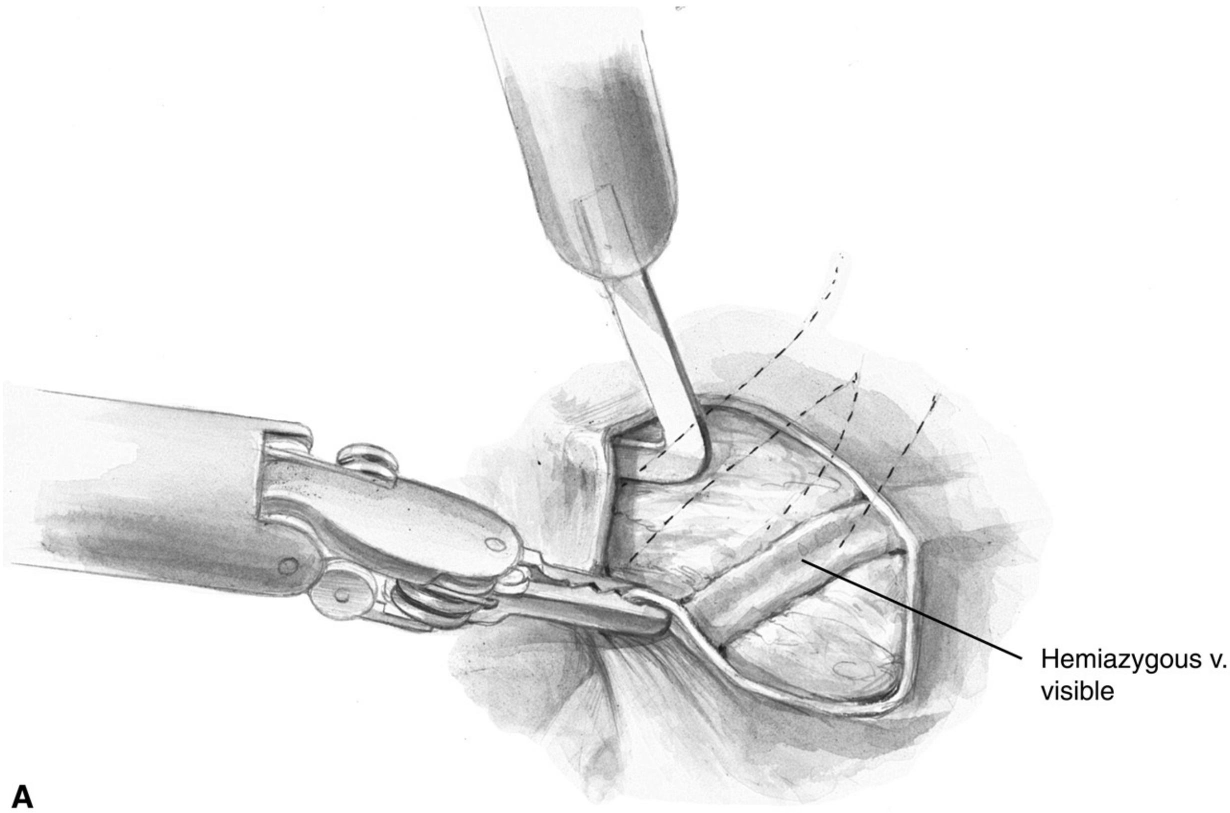


Figure 3 (A) The mediastinal pleura over the base of the left subclavian artery is opened first, leading to exposure of the other components of the vascular ring. The vagus nerve should be visualized before dissection, and the presumed course of the recurrent laryngeal nerve should also be kept in mind. (B) In cases of double aortic arch with an atretic left arch, both the ligamentum and the distal atretic left arch should be dissected out and divided. ao. = aorta; L = left; LA = left atrium; LCCA = left common carotid artery; LSCA = left subclavian artery; RCCA = right common carotid artery; RSCA = right subclavian artery; v. = vein.



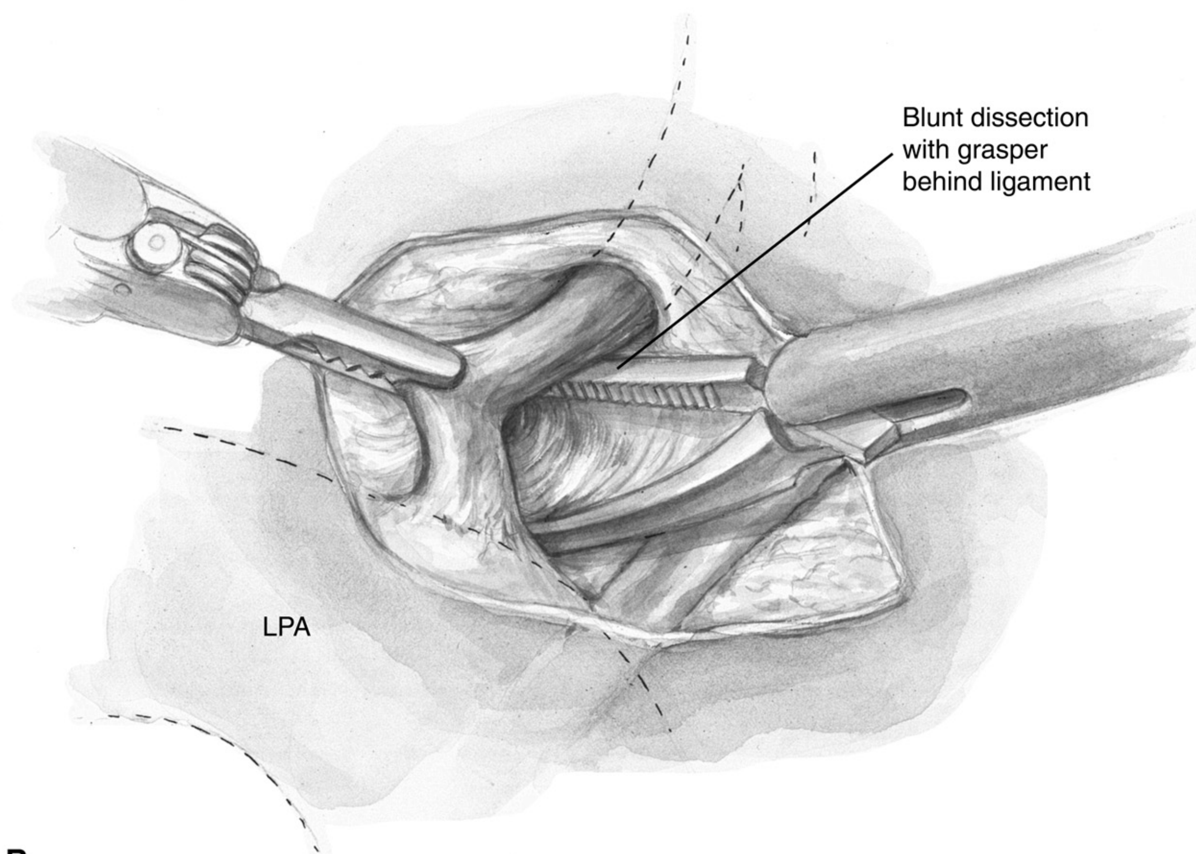


Figure 4 (A) A hemi-azygous vein frequently courses over the dissection site. This can be electrocauterized and divided, or clipped and divided. (B) Circumferential and wide dissection of the ligamentum is essential to ensure complete retraction of the ring components after division.

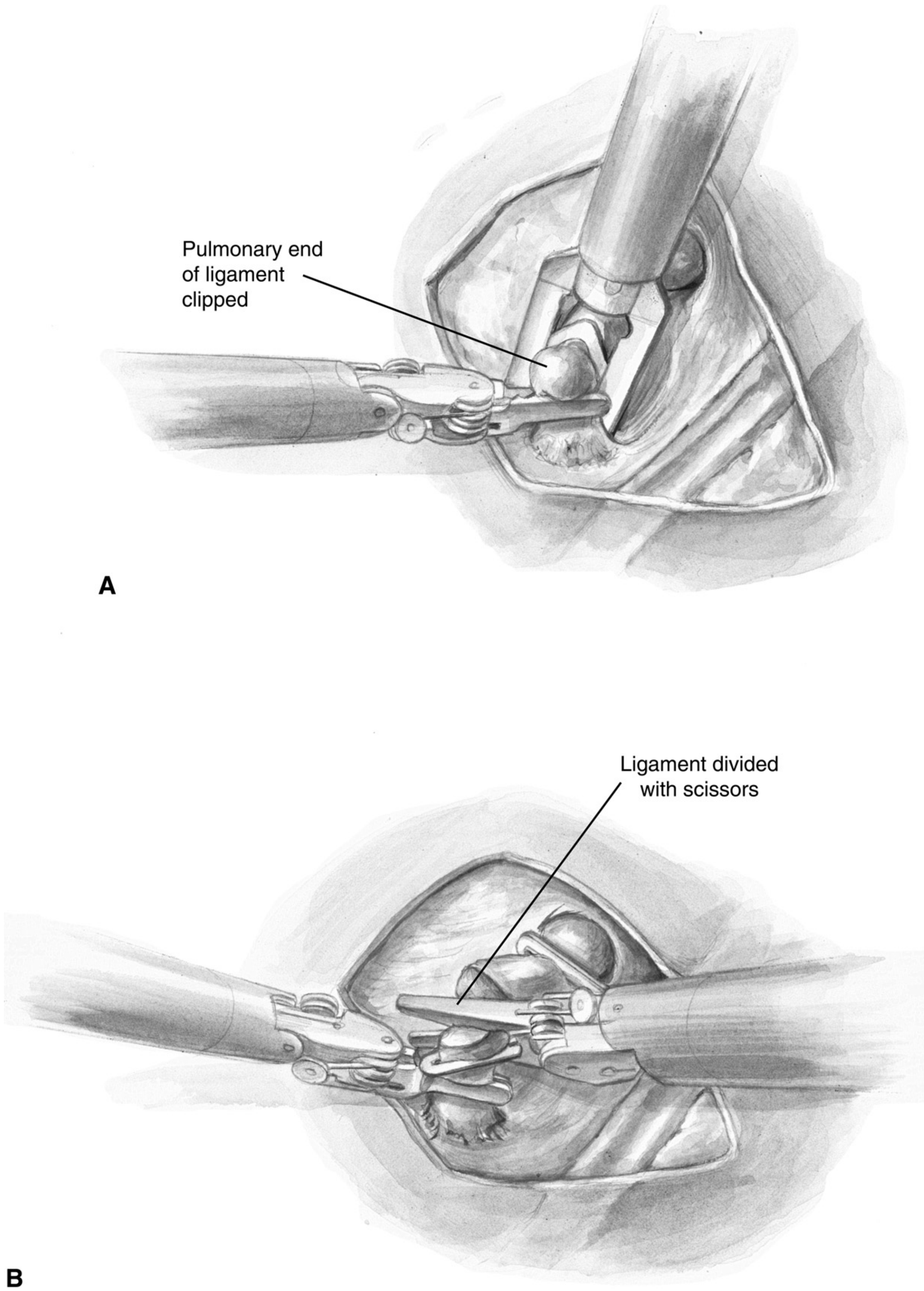


Figure 5 Once the dissection is completed, an endoscopic clip is applied on each side (A) and the ring is divided sharply with scissors or with electrocautery (B).

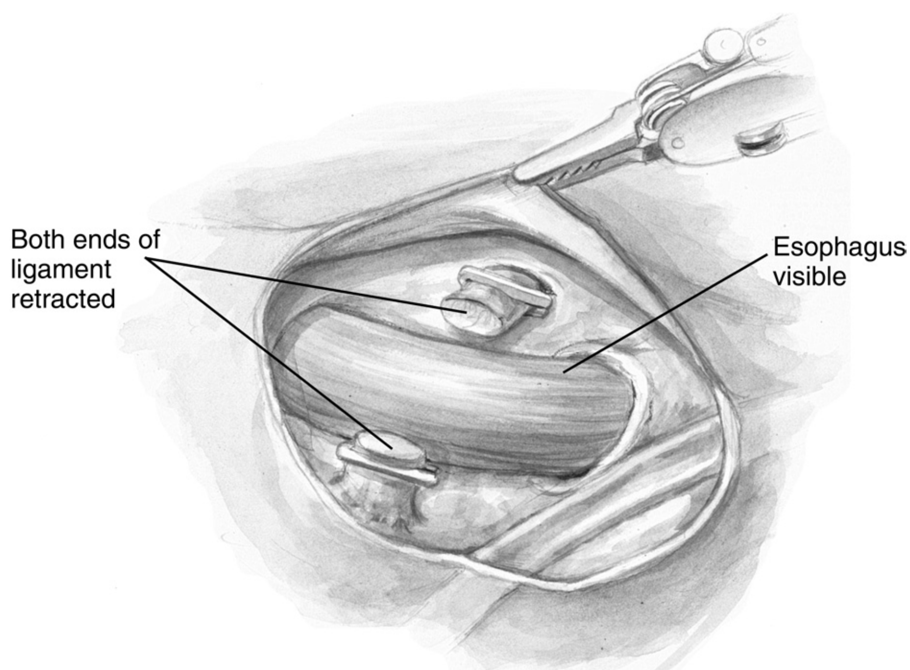


Figure 6 Once the ring is divided, both ends should retract briskly, and the esophagus should be visible underneath. If additional fibrous strands are crossing the esophagus, they should also be divided.

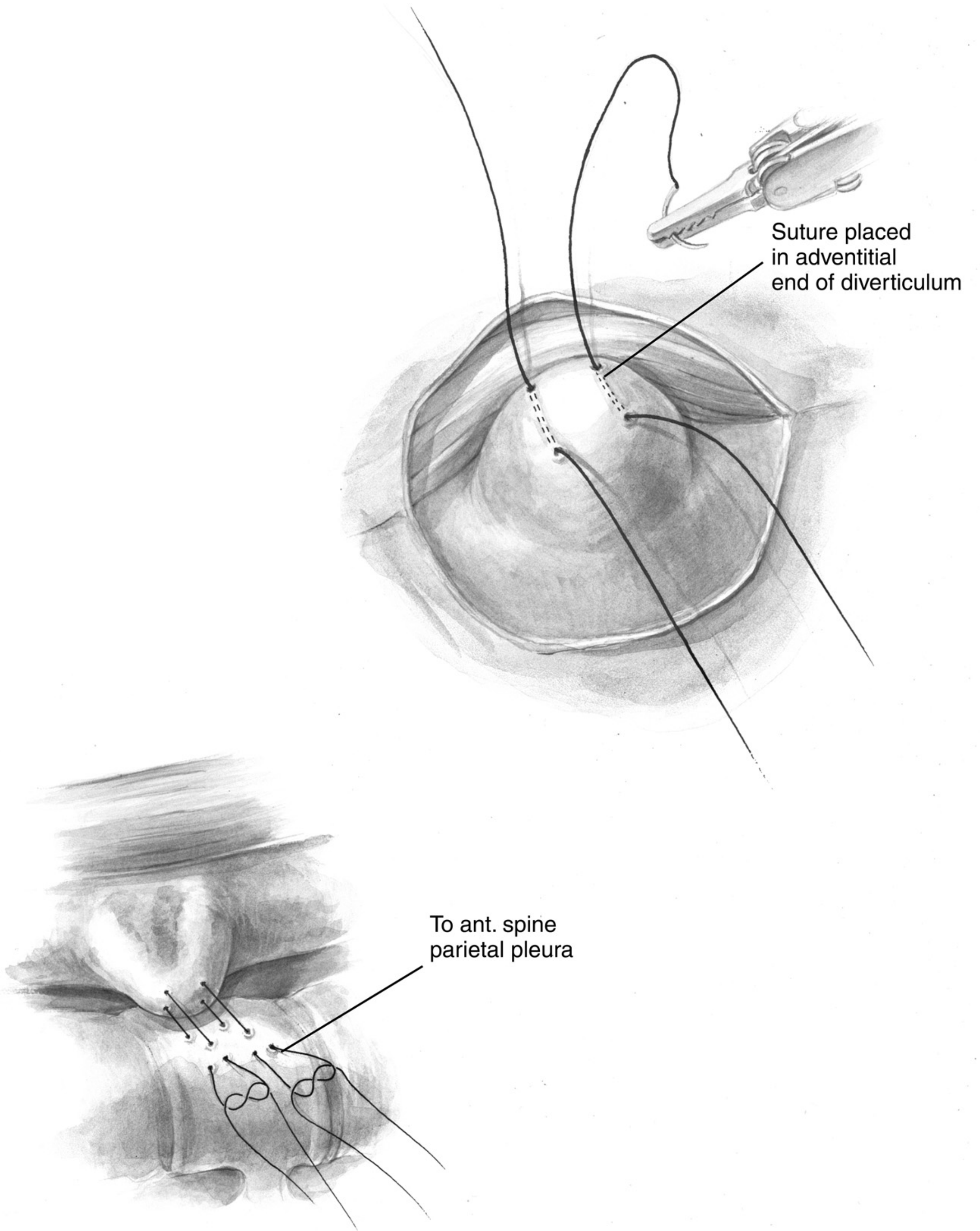


Figure 7 In cases where a prominent diverticulum is present and might lead to recurrent symptoms, the diverticulum can be robotically tacked to the posterior spine periostium using 4-0 Gore-Tex (W.L. Gore, Inc., Flagstaff, AZ) sutures.

References

1. Laborde F, Noirhomme P, Karam J, et al: A new video-assisted thoracoscopic surgical technique for interruption of patent ductus arteriosus in infants and children. J Thorac Cardiovasc Surg 105:278-280, 1993
2. Burke RP, Wernovsky G, van der Velde M, et al: Video-assisted thoracoscopic surgery for congenital heart disease. J Thor Cardiovasc Surg 109: 499-507, 1995
3. Shah RK, Mora BN, Bacha E, et al: The presentation and management of vascular rings: an otolaryngology perspective. Int J Pediatr Otorhinolaryngol 71:57-62, 2007
4. Le Bret E, Papadatos S, Folliguet T, et al: Interruption of patent ductus arteriosus in children: robotically assisted versus videothoracoscopic surgery. J Thorac Cardiovasc Surg 123:973-976, 2002
5. Mihaljevic T, Cannon JW, del Nido PJ: Robotically assisted division of a vascular ring in children. J Thor Cardiovasc Surg 125:1163-1164, 2003
6. Suematsu Y, Mora BN, Mihaljevic T, et al: Totally endoscopic robotic-assisted repair of patent ductus arteriosus and vascular ring in children. Ann Thorac Surg 80:2309-2313, 2005
7. Argenziano M, Oz MC, Kohmoto T, et al: Totally endoscopic atrial septal defect repair with robotic assistance. Circulation 108:II191-II194, 2003 (suppl 1)